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This article explains really well the setup required for a good pull pull system mostly used on our Large Scale rudders, without following these simple rules you risk burning out your digital servos. Credit goes to the original author for taking the time to write this article.

Ackerman- what it is, what it does and why we care.

A short history: In the early days of automobiles, no one could make a (4) wheel car steer correctly. Cars were often driven on wooden floors in the early days (demonstration purposes only- they were not yet practical anyway) and the versions with 4 tires were always leaving rubber marks behind. Tire life was terrible and the cars would often buck as they were turned; this is why there were so many three wheeled cars initially. The problem was known- as a car is driven in a circle, the inboard front tire (assuming it is front wheel steering) must make a smaller turning radius than the outside front tire. This is evident from tire tracks after a snowfall, a car turning in a circle will leave two distinct circles, one smaller than the other. This was not an easy problem to fix because each tire will be the inside the circle at some time and as the turning radius is changed, so too must this differential change with it. Enter one Mr. Ackerman- he proved his geometry using bedroom doors and a piece of string. Much later in time this principle was applied to automobiles. Sure enough, it works perfectly. All cars since that time have Ackerman built into the steering wheels as a necessity and it is not subtle; turn the wheels to full lock on any car (while stopped, of course), step in front of the car and note the direction the tires are facing. The inboard tire will be turned significantly further than the outboard tire; reverse the direction of the turn and Ackerman reverses also.

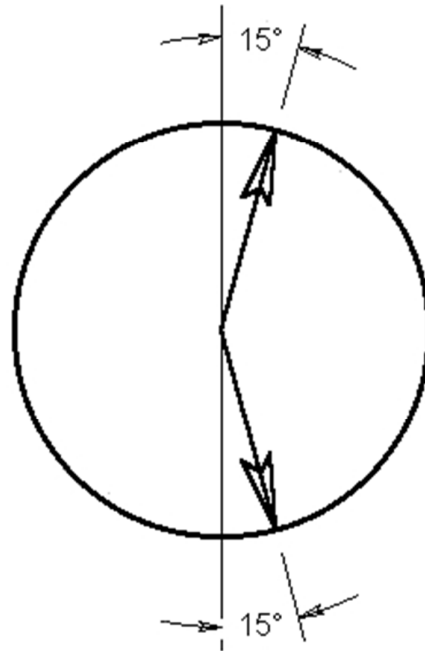
Ackerman is rotary to linear differential. For those who know what a cosine curve looks like, Ackerman simply moves the link between rotary movement away from $X = 0$. The most intuitive example of Ackerman, at least to me, is any piston engine. Notice that while crankshaft speed is constant, piston speed constantly changes from maximum near 90 degrees to <zero> speed at the top and bottom of the stroke. This is also the Ackerman principle at work.

I must confess to misusing the term. Ackerman is the specifically the geometry found on the steering end of cars. I have applied it to the control surfaces of model planes erroneously- it's a misnomer. However, I can't think of another word that describes it so well....

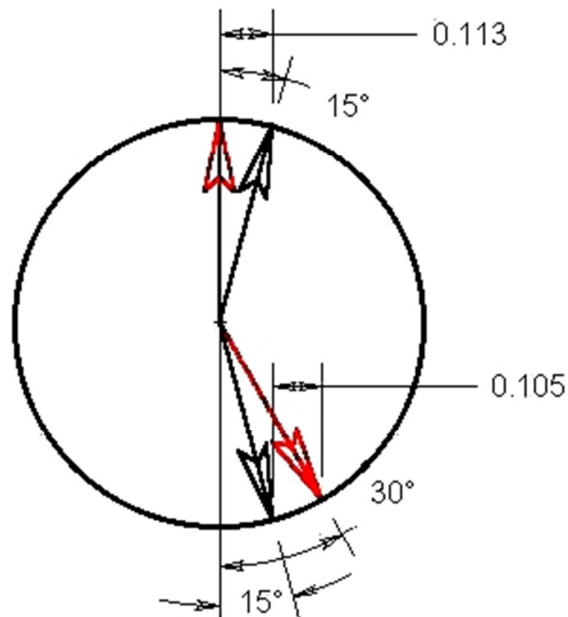


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For a visual example, look at the circle below:



This drawing shows two symmetrical points, each offset 15 degrees from the centerline, or 15 degrees away from 90 and -90 degrees. This is how Ackerman is introduced into our control systems. When this wheel is turned, anything attached to these points and held at -0- degrees (horizontal) will not move the same distance. See below:



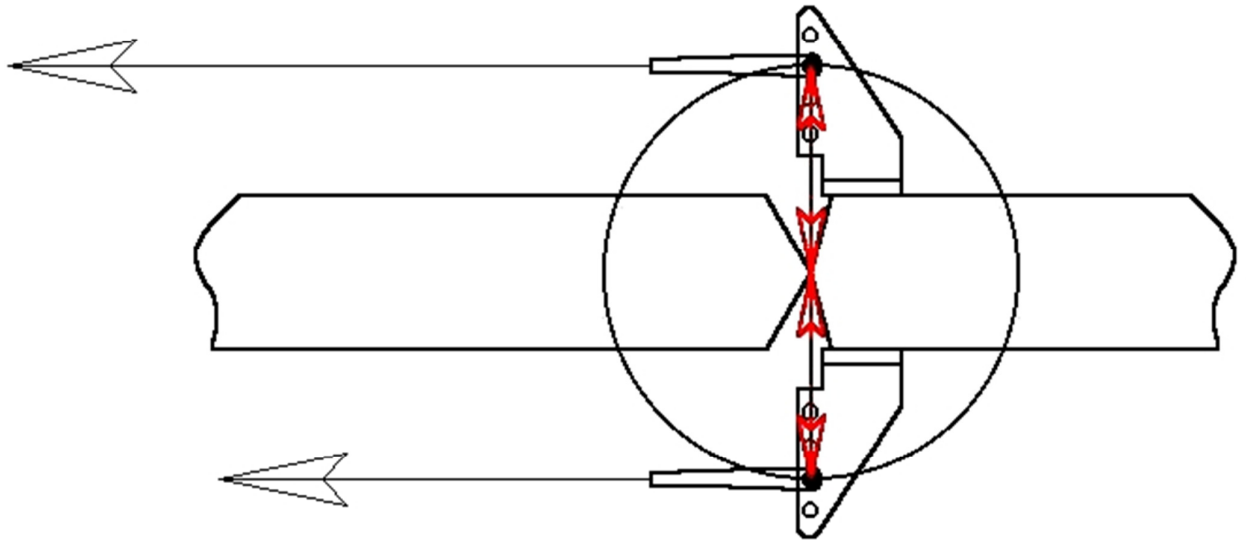
And here it is in a nutshell- Ackerman has made the linear distance different between the top and bottom. Notice that the wheel was rotated 15 degrees, and the top linear distance was 0.113 inches but the bottom distance is only 0.105 inches. This is what Ackerman does. Ackerman is dependent on the initial angles chosen- if +/- 90 degrees are chosen (that would be the top and bottom center of the circle), there is no Ackerman introduced and all linear motion will be the same for both points. The angle that will generate max. Ackerman is 45 degrees. This examples uses 15 degrees so that it's easy to see but in practice, we would normally choose something more reasonable for a pull-pull system....

The reason Ackerman works as it does is because any point attached to a disk that rotates makes both horizontal and vertical motion. In other words, a clevis attached to a rotating control arm will move both back and forth, but also up and down. What Ackerman does is alter this relationship; using Ackerman, we 'trade' some of our fore-aft movement for up-down movement, which we don't care about. This is exactly where the slack comes from.... the cable going slack is doing so because it's also moving closer to the pivot point (on a horizontal line). If this is not clear, try to visualize the movement that occurs between the two drawings above; the upper cable is moving a greater distance left - right than the lower cable is but the lower cable is moving a greater distance up - down than the upper cable is. Effectively, we are trading this up - down motion, which we don't care about, for a differential left - right motion, which we certainly do care about.



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next part in understanding the application of Ackerman is seeing where this circle and connection points is found on our toy planes. It would initially appear that there are no circles used as all we use are servo arms and surface control horns but this is not quite true as a circle can be drawn around any three points. This means that there really is a circle around both the servo arm and the control surface. As most servo arms are straight and therefore symmetrical, we can't easily introduce Ackerman at the servo end of the system so it has to be used on the 'other' end of the system. Look at the next picture for a visual reference as to how and where Ackerman is introduced into our toy planes.

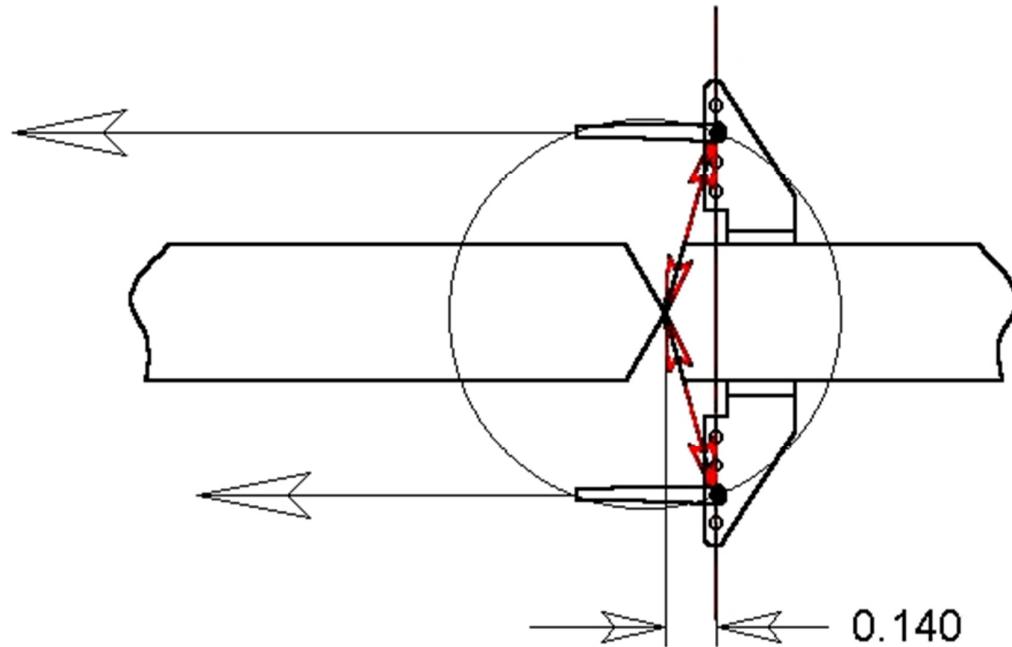


This is a typical control arm installation. We can draw a circle using the hinge line as the center, and sweeping right through the holes that the clevises (clevi?) attach to. The red line is shown for reference between the holes in the control horns. This drawing isn't the best but the forward flat part would represent the horizontal stabilizer, the aft portion would be the elevator, and the horns / clevises are shown mounted directly above and below the hinge line. This mounting scenario has NO ACKERMAN. It is fully symmetrical and will be absolutely linear. As one cable moves rearward, the other cable moves forward the identical distance.

The next view should make Ackerman usage clear:



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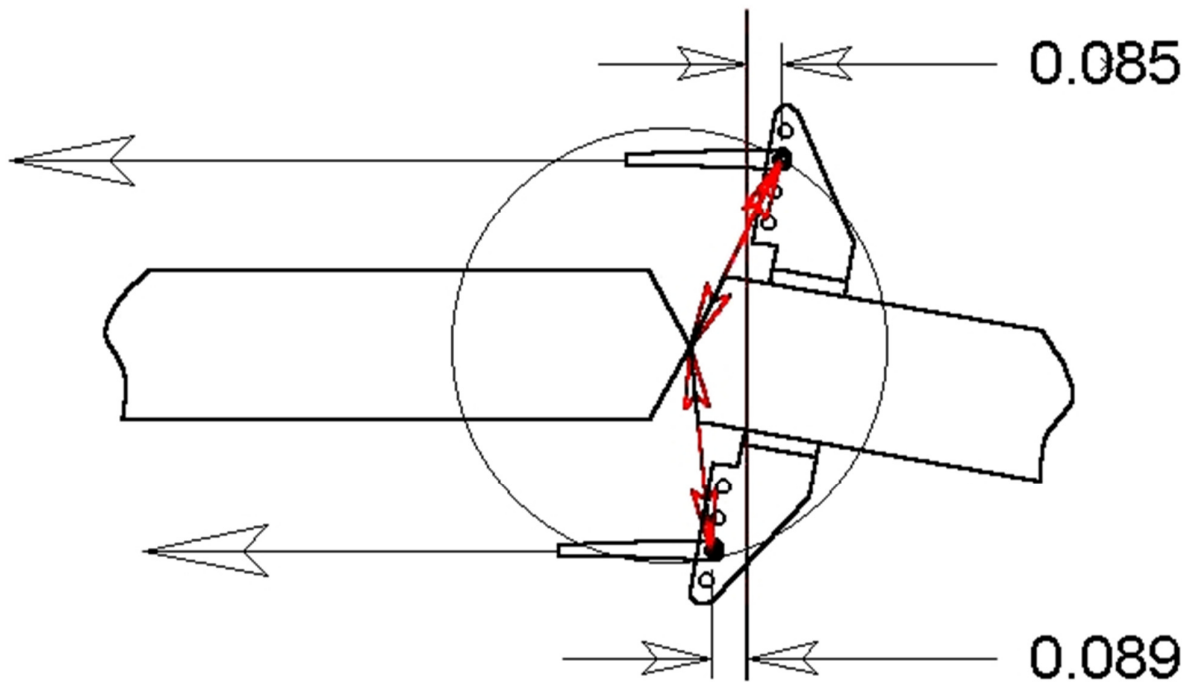


The horns have now been moved rearward 0.140 inches in relation to the hinge line. Note the red lines- these indicate the angle formed between the horn holes and the hinge line. As the bottom cable moves forward to deflect the flight surface downward, the upper cable will move rearward but NOT AS MUCH as the bottom cable moves forward. It is a distinctly asymmetrical system. This is also positive Ackerman; moving the holes in the control horns forward would create negative Ackerman, and this would be disastrous.



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Now watch what happens when this system is deflected:

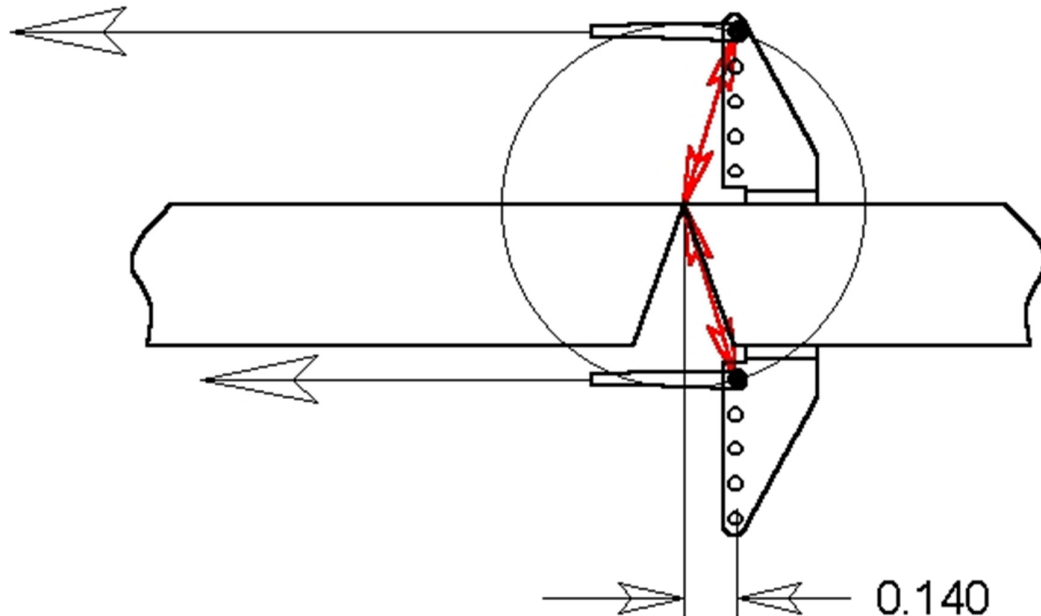


The control surface has been deflected 10 degrees but the cable travels are not equal- there is a .004" (inch) difference between the upper and lower cable movement. This will introduce exactly that amount, 0.004", into the non-pulling side of the cable, which is the upper cable in this case. Of course if the deflection is the other way (up), then the differential will also be the other way.

It also does not matter which side has the slack- as the airflow will always force the deflected surface toward the neutral position, the nature of the forces involves actually chooses which cable is taut and which is slack.

One other critical consideration: The pull-pulls must be centered around the hinge line rather than some other geometry like the center of the surface being controlled. This is not a consideration with pushrods but **MUST** be compensated for if using an offset hinge line.

Consider the example below:



This is exactly the same as the example above it but the hinge line is now on the top. The cable connection point must be placed so that the hinge line is the geometric center instead of the surface. Notice that the circle is centered at the hinge point and that the red arrows still indicate that each cable is the same distance from the hinge line. This causes the geometry of the cable system to go right out the window; each cable will not be straight but actually at an angle. More importantly, they will be at different angles. This is a prime example of using Ackerman- this system would be virtually impossible to compensate for if constant tension was the goal but using a bit of Ackerman will fix it up perfectly. The cables will now gain slack at slightly different rates but we don't care about this. A constant tension system would almost certainly result in a tight point somewhere other than the neutral (center) point.

I firmly believe that many people actually introduce Ackerman into both pull-pull and pushrod control systems without ever knowing that they have done it. Usually, the control horn is mounted behind the hinge line because of the bevel on the surface itself. In fact, this is how I found out I was using it..... I installed (2) pull-pull systems with great results (and Ackerman, although unwittingly) and then a third but that system became tighter as it was deflected (the dreaded anti- Ackerman :-). After sitting down and thinking about this for a while, blinding comprehension took hold. As a kid, I had read about Ackerman and his geometry; a gust of clear thinking made me realize that I was using it on my model, although by mistake and in one case, incorrectly.



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A few points on using Ackerman. It is not really desirable, but it is a wonderful tool for making absolutely sure that the tightest point in the entire servo (and controlled surface) travel is the neutral point. Slack in the system is not the goal; having the system NOT tighten as it moves away from neutral is. So how much Ackerman do we use, how do we measure it and is it critical? Not much, we don't, and no, it's not. I do not measure any angle or differential when I use a pull-pull system but rather 'cheat' by simply offsetting the control horns a small amount. In other words, when I install the horns, I simply line up the leading edge of the control horn with the hinge line and then move it back (aft) a slight amount, perhaps 1/16" to 3/32". I do not measure it but know that there is some Ackerman installed, and <some> is enough. This 1/16" or 3/32" (that's about 1.5 or about 2 mm for you metric types) is the measurement from the hinge line to the clevis holes on the horn; no other measurement matters.

There could certainly be too much Ackerman introduced during construction but this isn't likely. If the cables were attached in such a manner as to create a 30 or even 45 degree angle, then the slack introduced during deflection would be far too much, far too soon. That said, look at drawing #4 again and see how likely it is that this would happen- not very likely. With 3/32 inch of offset behind the hinge line, the cables will remain tight through approximately 10 degrees of deflection. After that, there is sufficient force on the deflected control surface, even at zero forward speed, due to prop wash. In fact, I do this all the time in the hover; the plane is not moving but the controls are all deflected a small amount.... no flutter because even if Ackerman causes a loss of tension in one cable, the prop wash will provide more than adequate force to hold the pulling cable taut.

There are apparently some that have the view that Ackerman, and the resulting slack in the non-pulling cable, will allow all manner of disastrous things to happen, starting with the destruction of the flight surface so controlled, and apparently ending with the death of all living things on planet Earth :-). Well folks, it just ain't so. It isn't necessary to understand the mathematical relationship to see that this will work quite well. One easy test is to put your hand out a car window while driving down the road- start off with it flat and horizontal, then rotate it a few degrees so that the wind is trying to lift it. Now drive with your hand in that position until the wind pushes it down or doesn't push it at all..... it won't happen. Compare this to a deflected surface- there will be no condition that would push a deflected surface the <wrong> way, or vary enough in pressure to cause flutter or any other undesirable condition. The important thing to remember is that once a surface is deflected even a small amount, one cable (the 'pulling' cable) is doing all the work while the other is nothing more than 'along for the ride' at that particular time.

Pull-pull controls are the best thing to hit model planes since sliced bread (which didn't hit model planes but was quite a step forward in it's own right :-). They work superbly and have no downside. Ackerman provides the icing on the cake so that pull-pulls become very easy to install and use. Ackerman also is a thing of beauty without downside provided it's used in a reasonable amount but even this is almost assured given normal construction.