Front-end options

I’ve always thought about the front end in the context of a nose cone, or the front end of an aircraft, but this doesn’t cover all possibilities. You can also picture it as being a collection of one large object, the head, and two smaller objects, the hands / arms. In this note we’ll look at the various options.

Will one position be faster than another? You won’t know until you test them relative to each other.

When I wrote the first draft of this post I thought it would be quite straight forward, but it isn’t. What you do with the front end alters the way the airflow interacts with the helmet, the torso and the skin suit.

Yaw (the effect of cross-wind) is also a factor that affects how a rider sets up the front end. Independent wind tunnel test results, the details of which have been posted elsewhere, have concluded that a small gap, or forearms touching, is more efficient than having a large gap between the forearms when there is significant yaw; however, the spacing of the arms can affect respiration, which can have a knock-on effect on power production, so it becomes a question of optimisation. Riders probably need a zero-yaw / minimal yaw set-up and riding position, and a cross-wind set-up and riding position.

Riders come in different shapes and sizes, and with varying degrees of flexibility and core strength. These parameters affect the sustainability of a rider’s position. Overall there are many factors that interact. What we are looking to do is find the best combination that gives the rider the best ratio of average power (for the duration of their event) divided by CdA, and with so many inter-related variables, this is quite a complex process. Let’s start thinking about this …..

The head, shoulders, arms and hands are effectively the leading edge of the top half of the rider / bike combination. The front wheel, and the front end of the frame, which form the bottom half of the front-end picture, are essentially fixed by the choice of equipment. Therefore, our scope for aero gains at the front end (without looking at equipment changes) is largely down to head and arm positions, relative to the rest of the torso, and helmet choice.
If we skip from aeronautical analogies to yachts for a moment (we are, essentially, dealing with fluid dynamics after all), we can think in terms of single hull dinghies versus catamarans and trimarans, as a way of visualizing how we present the combination of the hands, arms and head to the air, however, what I’ve found from testing myself, and multiple clients, is that it’s not as simple as one style fits all. Build and flexibility are significant factors. What works for one person may not work for another.

Optimizing the airflow over the body is a three-dimensional problem, not a two dimensional one. Minimizing frontal area will, likely as not, change your CdA, however, a flat surface can have the same frontal area as a nose cone, but one will have a much lower drag coefficient than the other. If you reduce the frontal area (A), the value of CdA will reduce if the coefficient of drag (Cd) stays the same. However, if changing the body shape to achieve the smaller frontal area also changes the coefficient of drag, increases it potentially, you may find that the value of the product, Cd multiplied by A, increases.

We must also consider what happens to the air after it has passed the first obstacle in its path. This involves visualization based on mental imaging of the airflow, and some prior experience of how airflow behaves when passing an object. Air behaves like a very thin (i.e. not viscous) fluid, so we can apply experience with fluid experiments to our visualization techniques.

There are two ways that the air can behave after it meets an object in its path, it can remain attached to the object so that the laminar flow is maintained, or it can detach leading to turbulence and friction between the turbulent air and the surface of the object. Going back to the fluid dynamics analogy let’s consider the difference between a canoe and a square fronted island ferry.

A canoe is relatively long compared to its width and it is pointed at both ends. Racing canoes are very narrow and very “streamlined”. They glide through the water at speed creating very little disturbance (wake) on the surface. The bow wave is attached to the front of the canoe, the flow stays reasonably laminar along the length of the hull, and the water recombines behind the canoe without much turbulence.

Contrast that to a flat fronted island ferry which is basically a block of metal being pushed through the water, and that creates a lot of disturbance. The bow wave will usually be several metres in front of the hull, and square-on to the leading edge of the vessel. The water around the sides of the hull tends to be drawn down to a lower level than the natural level that it would have if the hull was stationary. Behind the vessel the water rushes back in to fill the void left by the hull passing through the water.

Obviously, in these two cases, the frontal area of the vessels and displacement is vastly different, however, the difference in behavior of the fluid (in this case water) for the two shapes is clearly illustrated. The same would apply if the experiment were to be conducted with a canoe shaped piece of wood and a block of wood, if they are of equal length and frontal area, and just different shapes.
Where to start

Let’s make the assumption that we want to keep the “back-end” position unchanged as much as possible. We’ve had a bike fit that has given us the optimum saddle position relative to the bottom bracket, and we’ve then looked at power generation in the context of closing the hip angle to get a tucked body position. This basically fixes the position of the lower half of the torso.

The options for the position of the upper torso largely depend on an individual’s spinal flexibility and other physical constraints like core strength. The rider needs to be able to maintain the position for the duration of the event, and preferably for the warm-up as well, so this means that it should be reasonably comfortable. If it’s uncomfortable the rider will use mental energy, and probably some physical energy, attempting to maintain the position. Safety is also an important factor. The rider must be able to see where they are going and be able to handle the bike when in the aero position. They also need to be able to make a quick transition to the base bar if braking is required.

It’s worth doing some initial position experiments with the bike on a turbo trainer. This helps eliminate some extreme positions that look fantastic but are unrealistic. If the rider can’t manage ten minutes at tempo in a position on the turbo, then it’s unlikely that that position is going to work on the road under race conditions. Getting somebody to video the positions tested on the turbo is very useful. It will show how stable the upper body is when pedaling. Upper body stability really helps.

After doing some initial tests on the turbo the rider should have a pretty good idea of what drop they can handle, drop being the difference in height between the saddle, the part where your sit bones end up, and the pad height to the top surface of the pads. This is a maximum drop pad position but not necessarily the pad position for the most aero position. It just tells us where we don’t need to go.

Pad angle

Another aspect of pad positioning is the elevation angle of the pad. Angling the pads (up at the front) tends to result in a lowering of the elbows which, in turn, results in the shoulders and head following into a lower position. This, likely as not, will reduce frontal area, but, as mentioned previously, reducing frontal area doesn’t always lead to a lower CdA, however, many people find angled pads (and angled extensions) significantly more comfortable.

Traditionally pads have been mounted horizontally. This is largely due to the constraints of base bars and the mechanical characteristics of the pad mounting mechanism. For example, if you mount the base bar with its aero axis parallel to the ground, you normally find that the risers are restricted to being perpendicular to the base bar axis, and the extension clamps (that usually include the pad mount mechanics), mount directly on top of the risers. This results in a horizontal pad position by default. The extensions also end up with a horizontal section through the extension clamps. The Ventus II bars that were on my P3 are a good example of this. Base bars that support the angling of pads and extensions tend to come at either end of the price spectrum.

Low-end base bars, that have a round cross section near the stem clamp, usually have a combination clamp, one part that fits round the base bar and one part that clamps the extension. The base bar clamps can be rotated, and the angle of the extensions elevated, simply because the base bar is round
and the clamp can swivel. The angle of the pad clamps moves with the rotation of the extensions. An example of this type of base bar is the Zipp Vuka Alumina. Unfortunately, these low-end bars also tend to be relatively poor in terms of aero performance. If you are using this style of base bar with risers, then the whole riser stack will rotate when you rotate the clamp. That just doesn’t look right (!)

At the other end of the price spectrum some manufacturers include a rotational system in the extension clamps that mounts on top of the risers. These enable the extensions and the pad mounts to be rotated, usually within a range of zero degrees to 15/20 degrees. Examples of this type are the ENVE Smart System and TriRig Alpha X, although with the TriRig the rotating clamps are an optional extra.

There are ways to change the pad angle for the “traditional” mounts, either using custom wedges with existing pads, or using after-market pads that have a wedge integrated into the design. The range of angles is restricted as there is no rotational freedom, and you need to be careful with the screw heads, as most pads are counter sunk for horizontal mounting and the holes may need modifying when using wedges. Only the pad angle is changed when using this approach, the extension mount is affected.

**Pad width / Extension width**

As with pad angle, some pad mount systems are more adjustable than others. Most of the pad width movement is accomplished using multiple sets of mounting holes in the pads. If you go for custom after-market pad mounts you can specify where you want the mounting holes. This is great for when you’ve got your position nailed-down.

Extension width adjustment tends to be limited, or none at all, with the more expensive base bar systems. The low-end base bars, that use separate clamps, have a lot more flexibility but at the cost of other functions and aero efficiency.

**Choice of extension shape / rise**

There are a lot of options other than the traditional S-bend extensions. The choice comes down to two factors, comfort and aero performance of the resulting position. This is where we start to get into the need to test the position on the turbo initially, and then test aero performance in the field.

**So how do we go about finding the best front-end position?**

There is no option other than to test in the context of comfort/sustainability, power output and aero performance. We’ve already said above that we don’t want to change much, if anything, with respect to the back end, specifically not closing the hip angle, as this may have a detrimental effect on power, so we are going to just look at the front end, starting with the pads at their maximum “drop” that we have determined from testing on the turbo. If we were to raise the pads this would open the hip angle which, from general experience, is likely to help with power rather than compromise it.
There are a lot of variables to deal with, degrees of freedom in mechanical terms, so we need to take a scientific / structured approach to the test protocol and sequence of tests. It is also useful to have a benchmark position that can be tested periodically within a session, and also be used when a series of test sessions are performed on different days. This offers continuity and a degree of consistency across the test runs.

I still use the benchmark method as a sanity check in parallel with the instrumentation method. The benchmark position needs to be one that you are comfortable with as this will also be used for warm-ups and cool-downs at either end of a test session. The benchmark position can be changed for a more aero position as the set of sessions progresses. You just need to start the next session with the same benchmark position that you used at the end of the previous session to provide the continuity.

If you are lucky enough to have two bikes, then you can keep one set-up as a dedicated benchmark machine. This saves a lot of time “messing around” with mechanical changes. When I do test sessions with clients I use my machine (with me riding it) as the benchmark. This saves the client having to do multiple changes back to their benchmark that would eat into their tests time.

The three main variables that we are dealing with for the front end are: pad width, extension type (shape and degree of rise on the extensions), and if we are fortunate, extension/pad elevation angle. The multiple pad mounting holes usually provide the option of dishing the pads which adds another variable.

When creating a test schedule for a session we need to think in terms of what shape we are trying to achieve at the front end for each option:

Are we going for a nose cone style, so that would be higher hands, tucking the head behind the hands and looking over the thumbs?

Are we going with the arms close together, the single hull analogy, or with the arms separated, catamaran?

Are we going for a gap between the head (and shoulders) and the forearms, so that would be flatter extensions, and with that are we going for the arms close together or with the arms separated, and how does that choice affect breathing?

If we are going for arms separated what gap should we have? The permutations soon mount up, so it’s unlikely that you would get all options tested in a single session.

The first test session should focus on testing some extreme options against the relatively “normal” flat S-bend position with the previously established maximum drop. Ideally these tests need to be on a velodrome or a circuit, and definitely without traffic or other riders. The differences can be quite small so we need to keep the external factors as controlled as possible.
The test schedule might be something like this:

*First test as a benchmark*
Warmup laps about ten minutes
Ten-minute benchmark test

*Change pad width, if starting position was narrow then go wide, or visa-versa.*
Warmup laps about five minutes
Ten-minute test

*Change extensions (or elevate if mounts allow that) to raise the hands, same pad width as above*
Warmup laps about five minutes
Ten-minute test

*Revert to the original pad width*
Warmup laps about five minutes
Ten-minute test

*Go back to original extensions and position*
Warmup laps about five minutes
Ten-minute test

That’s 80 minutes of riding and about 20 to 30 minutes of mechanical changes, and that’s enough for one session. Testing different helmets with each position is an option. Helmet changes are quick, so you don’t need to worry too much about the impact that stopping has on tyre temperatures when you stop just to change the helmet.

Once you have processed the results from testing your first set of options you can start to look for the configurations that have the lowest CdA. You can then devise the test protocol for the next session using one of those low CdA positions as the benchmark, and planning to make small adjustments from that, to see if there are further gains to be made.
Here is my general thinking on what sort of front-end position suits different builds of rider:

Smaller flexible riders, that are dedicated to TT, can go with a tight tuck and an arm angle that matches the angle of their back. This gives them the appearance, from head-on, of a nose cone, and side on as a reasonably complete arrow head. Some air will go through the gap between the arms and the head and spread around the torso. This will help prevent a low-pressure area forming under the chest and, with trips on the hips, it may help with minimising the low-pressure area behind the buttocks. Riders with this style of position are best suited to helmets that sit mostly below the shoulder line when in position.

Larger riders and less flexible riders probably can't achieve a tight tuck, so bringing the arms up more, in front of the chest, can act as a screen. It's not the thighs that the arms are screening, it's the chest. These riders will carry their heads higher than their smaller more flexible (TT dedicated) counter parts. These riders are best suited to a helmet that is designed to be efficient (in aero terms) when a proportion of it is above the shoulder line, probably a short to medium tail helmet, and one to which trips are either integrated or have been added. The angle of the bars is also worthy of comment. Ideally the bars need to shape the airflow that will go under the body. If the angle of the bars is too steep this may have a negative effect.

My hypothesis is that using additional risers to bring the bars / hands up is a better solution than keeping the pads at the same height and using hi-rise extensions. My thinking is that a shallower angle of attack by the forearms is likely to produce lower drag than a steeper angle. I've only done minimal testing of this hypothesis (on myself) currently.

I think it was Taylor Phinney who used something like 120mm of risers on a Trek SC9 a few years ago to achieve a position like this. This style of position would help the current GT riders, and other riders that compete in events with UCI conformance requirements, to meet the UCI 10cm rule.

To summarise:

I think that once the forearm angle gets above 30 to 35 degrees the increased frontal area of the arms, and the angle of attack, are likely to have a negative effect on drag.

Some helmets work better than others for riders that hold their heads such that a significant amount of the helmet is above the shoulder line.

Larger helmets (wider) are quite possibly better than smaller (narrower) ones as the helmet shape is far more aero than the shoulder / torso area that it is covering in terms of frontal area.

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Ends