FRAMES

It's compromise rather than the 'perfect frame'

says DAVE MOULTON

QUITE often during discussions on cycle design I hear people say it is pointless trying to design a machine with a natural position for the rider, because man's legs are designed for walking or running, and therefore the pedalling action is unnatural.

But if this is so, how about for example the action of sawing a piece of wood, or digging a hole in the ground; are these also unnatural actions?.

During everyday life the human body is called upon to, perform literally millions of physical tasks, large and small. In carrying out these tasks it usually adopts a position automatically, whereby the task is carried out with the maximum efficiency.

Imagine, for example, you are putting a wood screw into a wall, you automatically position your legs and arms and the rest of your body to get maximum power to the screwdriver. If the screw is in a high position you stand on tip-toe, in a low position you bend your legs; you don't even have to think about what you are doing, the body adapts automatically.

If you look upon the action of pedalling a bicycle in this light, then it is no more unnatural than any other action.

The only trouble is that the design of the bicycle, and in particular the design of the frame, often restricts the rider from adopting the natural position his body wants to take.

To go back to the wood screw in the wall, if you tried to adopt any other position than the natural one, you would only be making the job more difficult for yourself.

Having said this, let me point out that it is not easy to design the "perfect frame". If the frame builder was designing a stationary pedalling machine, then it would be comparatively easy to get the rider in a position for maximum efficiency, but with a bicycle frame the builder often has to compromise because of certain restrictions placed upon him.

The biggest of these is that two large wheels have to be placed within a certain wheelbase. This is not to say that I am against large wheels. Unlike my namesake Sir Alex Moulton (no relation), inventor of the small-wheeled bicycle which revolutionized the design of the shopping-type bicycle, I believe that large wheels are necessary on a racing cycle for reasons of stability. However, they do sometimes present problems, especially on smaller frames.

Take the example of a frame for a rider with long thighs and a short body. The long thighs suggest a shallow seat angle, which means that the seat lug would be quite a way back behind the bottom bracket. Then because of the short body, a short top tube would appear to be ideal. The frame builder then wants a certain head angle and fork rake, only to find that the front wheel is now too close to the bottom bracket. The pedals or toe-clips overlap the front wheel, and the front wheel may even touch the down tube.

So the frame builder has to find some way to lengthen the front centres (the distance between the centres of the bottom bracket and front wheel spindle). This can be achieved by lengthening the fork rake, or making the head angle more shallow, or by compromising and making the seat angle slightly steeper and the top tube slightly longer.

I would prefer to do the latter, as to alter the head angle and fork rake would affect the handling characteristics of the bicycle. If the seat angle is slightly steeper than ideal the rider can adjust his saddle to get a good position. A shorter handlebar stem would compensate for the slightly longer top tube.

While on the subject of the wheelbase measurement, many riders seem to think this is the most important measurement on the frame, some to the point of being obsessed with short wheelbases.

The average front end measurement on frames I build is 23-inch (58cm) and the rear centres 16-inch (40.5cm) making a wheelbase (measured straight across) of around 38½-inch (98cm). If your bicycle handles well and gives you a comfortable riding position, why worry what the wheelbase is? To insist on a certain wheelbase only places further restrictions on your frame builder.

What, then, is the most important measurement that the rider should concern himself with?

I would say without a doubt the frame size, or seat-tube length (measured from the centre

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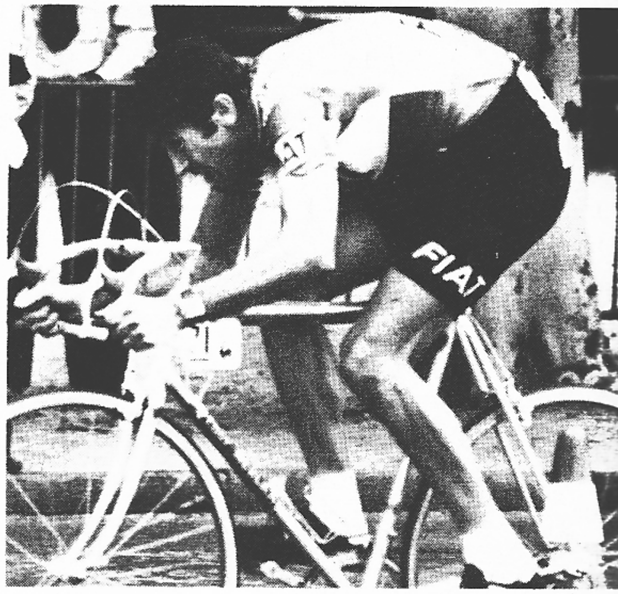

PROPULSION power doesn't come only from the legs, as this shot of Eddy Merckx in a Tour time trial shows. It comes also from the muscles of the arms, shoulders and back. The machine should be designed so that these muscles can work most efficiently.

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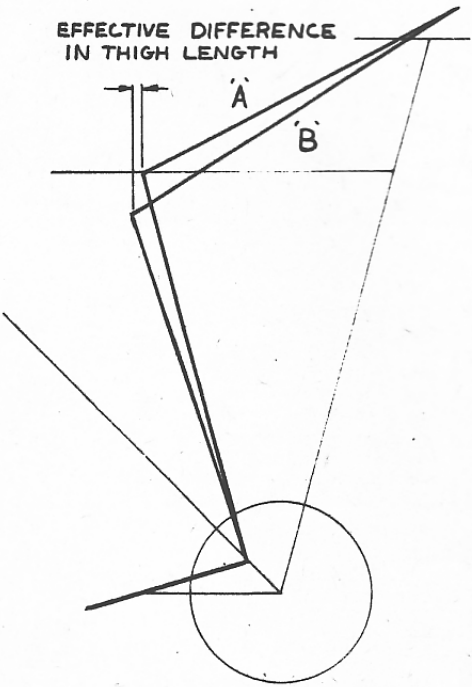
Fig 1.



of the bottom bracket to the top of the seat lug).

Many riders use a frame that is too big for them, or I could say a frame that is bigger than is necessary. The smaller the frame, the lighter it is, and also it is more rigid, so why use a bigger one if you don't need it?

The trouble is that many riders start their cycling careers on a second-hand frame which they become used to, and when they eventually order a new frame they order one the same size, never checking what their correct size should be, and often going for years on frames that are too big. I say frames that are too big, because I rarely come across a rider on a frame that is too small, except in the case of a schoolboy who has outgrown his.

The method I use for calculating frame size is to say it equals two-thirds inside leg measurement (measured crotch to floor in stockinged feet). For example, 33-inch inside leg equals 22-inch frame. This I find is much better than the old method of saying inside leg measurement less 10 or 11 inches, which presupposes everyone has the same amount of seat-pin showing irrespective of the rider's height. With the two-thirds method the taller rider has more seat-pin showing, which compensates for his longer arms and body.

I am against complicated

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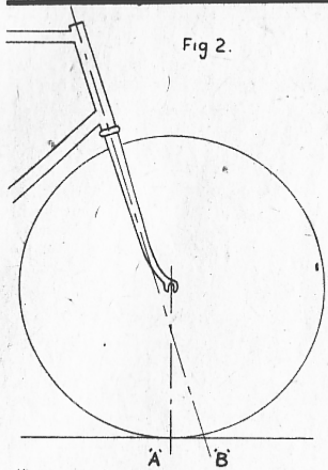

formulas to work out actual saddle height and other measurements; these rarely work out in practice because the measurements of limbs etc vary greatly from one rider to the next. Take the much-quoted Loughborough Formula — a distance from pedal face to the top of the saddle equals 109 per cent of inside leg.

This is all right as a guide, in fact I have used it myself when designing frames, but this measurement was arrived at from an average of many riders; only a small minority are average, the rest are either above or below that average. Also, saddle height is dependent on other factors, such as saddle width, thickness of soles on shoes and shoeplates, also the bone structure and the amount of flesh on the rider, whether he be a heavy or light build.

If the frame size is estimated at two-thirds inside leg this usually allows plenty of scope for adjustment to get the correct saddle height.

So, having got the frame size correct, we come to the seat angle and the top-tube length, which determine the rider's position in relation to the pedals. Before we decide what position this should be we must analyse just where the power to the pedals is coming from. From the legs obviously, but also from the arms, shoulders and back, the upper body acting as an anchor to hold the body in position while the legs thrust with more than the rider's actual weight. Look at a photograph of a rider in full flight and see the muscles standing out on his arms to know that this is so.

I referred to the human body adopting an automatic position to do a job more efficiently. A good example of this is a rider getting out of the saddle and standing on the pedals to climb hills, or for extra power to wind up a sprint. This is a natural action. If you teach a young child to ride a bicycle, soon after he has learned you will see him out of the saddle when the going gets tough, or when more speed is called for. He has not been taught to stand on the pedals, this comes naturally.

Why do we do this? It is not just to get our weight over the pedals; as I have already said we often pedal with more than our body weight anyway. It is to get our body over the pedals so that the legs can thrust straight downwards, and also to get the body nearer the hands and arms which are acting as an anchor, and putting an opposing force to the downward thrust of the legs. It's like lifting a heavy weight; you don't lift it at arm's length, you lift it close to your body.

Getting out of the saddle is all right for a short burst of power, but it is tiring, you feel unstable, and there is a limit to the rate at which you can pedal in this position. But it does give us a clue to what position the body, arms, and hands should be in.

If we were designing our stationary pedalling machine we would probably have the body upright directly over the pedals and the hands holding on to handles on either side of the body. But as it is a racing bicycle that we are designing we have to compromise again.

Wind resistance is the biggest factor against speed, so it is very important to adopt a low streamlined position with the back horizontal. Arms should feel neither restricted nor stretched. I have pointed out the importance of the hands being close to the body. However, they should not be so close that it is an effort to get back horizontal. Also if the arms are restricted there is a possibility of them splaying outwards, which would increase wind resistance.

Arms should not be stretched either; apart from the reasons already given, this is one of the causes of backache on long rides. With the arms stretched out the spine is constantly under tension. The effort of holding the upper body in this position while the legs are thrusting causes backache.

Imagine walking in a stooped position, carrying a weight at arm's length; the strain on the back would be tremendous. The effect is the same, but many riders do not realize just how much work their arms, shoulders and back are doing.

The seat angle should be such that it allows the centre of the knee to be directly over the pedal on the downward stroke. It is a matter of leverage. To have the knee too far behind the pedal is to add to the effective length of your thigh, plus the part of your foot which is extended beyond the knee. This is why, if the seat angle is too shallow, the rider ends up sitting right on the front tip of the saddle when making maximum effort. It is the body taking up its natural position again. It is acceptable for the rider to move slightly forward, but not to move right to the tip of the saddle, as this has the same effect as the saddle being too low.

Generally speaking I find that road frames of 23 inches and over can have a 73-degree seat angle, this angle increasing by one degree for every inch reduction in frame size; thus — 22-inch = 74-degree seat; 21-inch = 75 degree; 20-inch and under 76-degree.

Steepening the seat angle as the frame gets smaller also allows the top tube to be made shorter for the smaller frame, frames in the middle range being "square" with the top tube the same length as the seat tube. The larger frames will have their top tube shorter than the seat tube. This is because we are compromising, as explained earlier, to keep the wheelbase within reasonable limits. The same reason applies to the smaller frames, which have top tubes slightly longer than the seat.

There is another reason for the larger frames having a shorter top tube; this is because tall people are generally not scaled-up models of small people. A tall person usually has longer legs in relation to his body length, therefore if he has a 24-inch frame he does not need a 24-inch top tube, especially if you also take into account the extra saddle height in relation to the handlebars. The opposite is true in the case of the short person.

Seat angle I find can be linked to leg length, and therefore frame size rather than just thigh length. This is shown in Figure 1. Two riders, A and B, have identical leg length, and therefore use the same size frame. Rider B has a longer thigh than A, but because their legs are identical length it follows that B has a shorter lower

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leg. The drawing shows the position of the two riders' legs when the pedal is in a horizontal position on the downward stroke. As you can see, there is very little difference in the position of the two riders' knees.

Of course this only gives a general outline; a true made-to-measure frame would mean slight variations in the angles and tube lengths, but if "off the peg" stock frames were made to these dimensions they would be more suitable over the whole size range than the usual 73-degree parallel frame with a 22½-inch top tube irrespective of size.

For road frames I generally make the head angle 73-degrees and the fork rake 1¼ inches constant throughout the range of sizes. This is because I find that this combination gives ideal handling characteristics for general road work. Some frame builders argue that the head angle should vary with the size of the frame, but I feel that they are probably doing this to shorten the wheelbase rather than add anything to the handling characteristics of the bicycle.

Look at Figure 2, you will see that a line drawn through the centre of the head tube meets the ground at a point B, which is in front of point A, the point where wheel contacts the ground. The difference between A and B is known as the trail. This trail is essential because it not only provides a castor-action which keeps the bicycle going in a straight line, it provides self-steering, in that the machine can be steered by leaning into corners.

When the rider leans to the left the head tube moves to the left and so does the wheel at point B. The tyre on the road at point A acts as a pivot, and so the wheel turns to the left. When the rider moves himself upright the bicycle straightens up assisted by the castor action.

You can see from Figure 2 that a steeper head angle means less trail, because point B moves closer to point A. By the same rule a longer fork rake also means less trail, because point A moves closer to point B. So the worst combination is a steep head angle and a long fork rake, because you would have little or no trail. You could even get to the stage where point A is in front of point B. Then you would have a "positive" trail and the bicycle would be unridable, because when you leaned to the left it would steer to the right.

Incidentally, that is why motor-pace bicycles have the forks round the "wrong way". A very steep head angle is necessary to get the cyclist up close behind the motor-cycle and the forks have to be raked backwards to keep a "negative" trail.

Getting back to the road-racing cycle, more trail gives oversteer, which means the bicycle takes a corner tight. Less trail means understeer which means you take the corner wide, and this, as well as losing time, can be very dangerous, as you can end up on the wrong side of the road facing oncoming traffic.

Too much trail makes the bicycle feel unstable when out of the saddle, so again we have to compromise. I find that 73-degree head angles and 1¼-inch fork rake give just the right amount of trail, giving slight oversteer, which counteracts the centrifugal force when cornering, and the rider can still keep a good line.

Track bikes do not have to go round corners because the banking has the effect of making it as if the rider was travelling in a straight line. So less trail is necessary, although you must have some trail to keep the bicycle going straight.

There is a well-known theory that a bicycle with a steep head angle will go faster in a sprint. I have found no proof to support this theory, only that a bicycle with a shallow head angle may feel a little unstable when the rider gets out of the saddle to jump away in a sprint. This is because the rider out of the saddle tends to sway the bicycle from side to side, to a greater or lesser degree according to his style of riding. A bicycle with a steep head will feel a little more lively at the front end when the rider is out of the saddle, because there is less tendency for the front wheel to move as the bicycle is swaying from side to side, there being less trail.

But there is also a disadvantage in this situation. Because the head angle is steep, the rider's weight may be well over the front wheel spindle, so that a sudden lunge forward will transfer the weight to the front of the bicycle and cause the rear wheel to skip, losing valuable traction just when it is most needed.

Once the rider has become used to the feel of his bicycle there is no evidence to say that a slightly shallower head is any less fast in a sprint.

I have mentioned several times the word compromise. There are many differing situations during a race, and your bicycle has to be designed to cope with all these. In a road race, for example, you need a bicycle on which you can climb hills out of the saddle, descend hills fast, corner with complete safety with the minimum of slowing down, and hold a straight line in the sprint at the end.

It is no use having a frame designed just for the sprint at the end of the race if your bicycle handles badly and dumps you in the road miles from the finish, because you are tired and not concentrating.

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